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(71)(72) Applicant and Inventor: ZYLBERSZAC, Mojzesz [SE/SE]; Kristinelundsvägen 12, S-171 57 Solna (SE).

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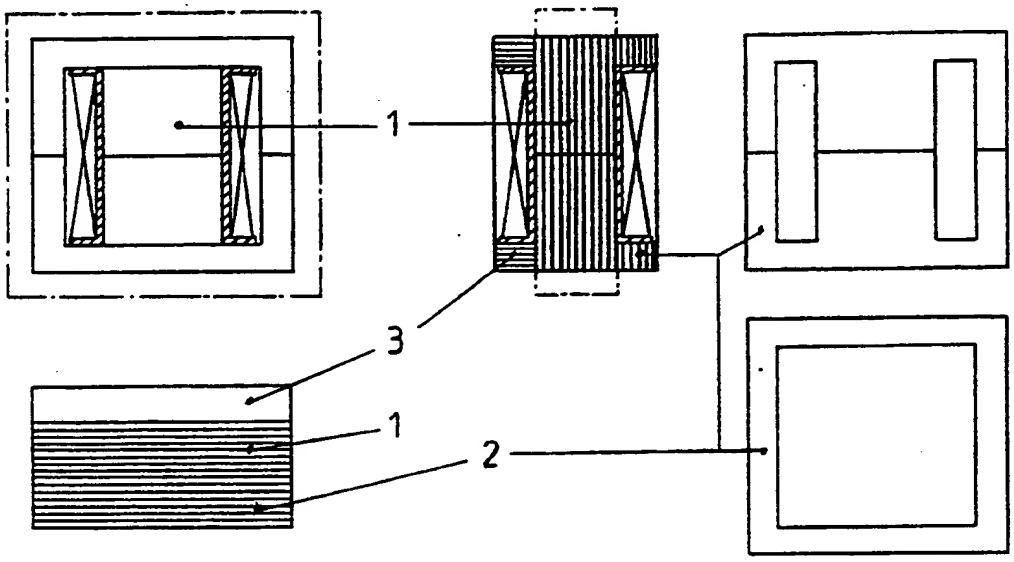


(57) Abstract

A soft magnetic core in an electromagnetic circuit made from sheet cutouts or wound sheet tape r sintered ferrite material comprises different shapes. and methods of forming a core so that the capacity as a function f the volume is increased.

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# SOFT MAGNETIC CORE IN A CLOSED ELECTROMAGNETIC CIRCUIT

## Technical scope

The present invention relates to a soft magnetic core in an electromagnetic circuit.

## State of art

Cores for transformers, certain types of motor and other electromagnetic circuits are traditionally made from soft magnetic material in the form of sheet cutouts or tape cores or from sintered material (ferrite), whereby a part of the closed magnetic circuit is encompassed by a winding. That part of the sheet package (magnetic circuit) which is not encompassed by the winding has at least the same area as the part which is encompassed by the winding. As the coil is wound above only a part of the form of the core and the winding takes up considerable space, this means that the parallellepiped encompassing the magnetic circuit takes up space along the outer circuit which is not utilised, i.e. which comprises neither winding nor core.

As a result the capacity of such magnetic circuits as a function of volume is not optimal, since parts of the volume are utilised neither for the winding nor the core.

Inasmuch as it is precisely increased volume of winding and increased area of the magnetic circuit which give rise to increased capacity, the non-utilised space must be used for the magnetic circuit or winding if the capacity as a function of volume is to be increased.

The specified aim is achieved by modifying the shape of the core so that vacant space is taken care of.

Such technology is employed according to the Swedish patent specification 69233, according to which vacant space in a transformer for 3-phase current has been taken care of by two packages of sheet cutouts being placed at right angles to the core stacks, thus causing the core stacks to be magnetically connected.

## Particulars of the invention

In order to increase the capacity per unit of volume use is therefore made of the inventive idea of utilising the volume which with traditionally designed magnetic circuits is unutilised and placing the core within the circuit. Claims 1-4 comprise, according to the invention, cores consisting of sheet cutouts in which the non-utilised space is taken care of inasmuch as the flux area in the outer circuit is modified by reducing, in first

sheet cutouts, the flux area in the sheet cutouts with closed circuit loop, and in compensating the reduction by increasing the flux area in second sheet cutouts connected parallel to first sheet cutouts in the outer circuit.

The invention according to claim 5 entails the following advantages by comparison with the Swedish patent specification:

If the area of the outer circuit is half as large as that of the inner circuit half the magnetic flux passes, in conventional manner, through the first sheet, thus causing the reluctance to be lower.

This design entails a lower number of components and makes it possible better to meet the requirements as regards dimensional accuracy of the air gap. Furthermore, the core design of the first part makes it easier to stay within the positional tolerances specified for coil formers and the core, thus facilitating assembly at the specified location and mechanisation of the production process. The fact that there is more waste is less important considering the advantages when producing cores with reduced dimensions in relatively large numbers.

As can be seen, claims 1-5 solve problems of the same type as patent specification 89233 but in a different manner and also in a different sphere. Claims 6-9 relate to electromagnetic circuits with tape cores. Also in this case non-utilised space is taken care of, at least in part. The technical effect is achieved by combining parts of tape core with magnetic joints, not in conventional manner by means of surfaces at right angles to the longitudinal direction of the core tape but by the side edges of tape sheets forming part of C-shaped tape core bodies. Furthermore, with cores in accordance with claims 7 and 8, the shape of the inner circuit is novel from the point of view of tape core technology.

On the other hand, the modification of the configuration of cores according to claim 9 entails, by comparison with conventional tape core shapes, a modification of the flux area in the outer circuit.

Since the direction of the magnetic flux when making use of C-shaped core parts, the parts of which bent towards the side extend forward beyond the ends of this coil, is both in the longitudinal direction of the tape and at right angles to the latter, the structure of the material in these core parts need not be oriented.

The same types of core with high capacity per unit of volume as are used with soft magnetic cores consisting of sheets are used according to claims 11-12 for cores made from sintered soft magnetic ferrite material, these being comparable, as regards high capacity per unit of volume, with

the so called X-cores, which are also made from sintered material.

Description of figures

The invention is described in detail below, with reference to figures 1-11 relating to embodiments for transformers and a motor. The figures refer to cores but also coils are mentioned by the way.

In general no reference is made to the problem brought about owing to the need of arrangements for mounting the electric magnet on a holder or a pattern card. No mention is made either as to how different sheet elements are held together at the specified location. It is suggested that this may be done by means of laser welding, which entails minimal welding seams and, as a result, minimum impairment of the structure of the material. As a result, there is no need for cumbersome arrangements in order to hold the sheet elements together at the specified location. Nor is there, in general, given any indication what measures are necessary in order to achieve the required air gap in the magnetic circuit. Sintered soft magnetic cores are joined by gluing and other methods.

Figures 1-5 relate to cores consisting of sheet cutouts and to claims 1-5.

Figures 6-9 relate to tape cores and to claims 6-10.

Figures 10-11 relate to cores of sintered, soft magnetic ferrite material and to claims 11-12.

Embodiments

Figures 1-11 illustrate claims 1-12.

Figure 1 shows sheet cutouts referred to as first sheet cutouts according to claim 1, the surface of which is reduced by comparison with conventional types within the outer circuit, within the confines between the dash-dot lines and the fully drawn lines.

Figure 2 shows a sheet cutout package consisting of first sheet cutouts (1) with reduced surface round about, which are assembled with two sheet cutout packages consisting of second sheet cutouts (2) or a tape core (3), as a result of which the reduction of the core area of the first sheet cutouts/outer part has been compensated.

Figure 3 relates to first sheet cutouts (1) with reduced surface at the outer part and second sheet cutouts (2), as a result of which the reduction of the core area of the outer part of the first sheet cutouts has been compensated.

Figure 4A shows a sheet cutout package consisting of first sheet

cutouts (1) assembled with two sheet cutout packages consisting of second sheet cutouts (2) and two sheet cutout packages consisting of third sheet cutouts (7). The third sheet cutouts (7) conduct the magnetic flux from the first sheet cutouts (1) to the second sheet cutouts (2) and cause the reluctance to be low.

Figure 4B shows examples of various forms of third sheet cutouts (8-11) and different ways of conducting the magnetic flux from the ends of the inner part of the first sheet cutouts (4) to the second sheet cutouts (5) or to tape core (6), so as to cause the reluctance to be low.

Figure 4C shows a traditionally designed motor comprising a core with only one type of sheet cutout (12).

Figure 4D shows a motor of the same capacity designed with a core according to the claims, the volume of which is lower.

Sheet cutout (13) has the same area within the inner part, zone A, which is encompassed by a coil, but it has half the area within zone B and zone C. Sheet cutouts (14) in the outer circuit are assembled parallel to sheet cutouts (13), as a result of which the reduction of area within zones B and C is compensated. Sheet parts (15) conduct the magnetic flux from sheet cutouts (13) to sheet cutouts (14) and cause the reluctance to be low.

Figure 5A shows a package of sheet cutouts (1) with reduced surface A and B in the outer part assembled with sheet cutouts (2) or (3), as a result of which the reduction of the core area is compensated.

Figure 5B shows a package of sheet cutouts (4) with reduced surface C and D in the outer part assembled with sheet cutouts (5), as a result of which the reduction of the core area has been compensated.

Figure 6 comprises a core unit with two C-shaped tape core parts (1), the inner part of which is encompassed by a coil.

The outer parts of the core unit are connected by one or two tape core parts (2) or a C-shaped package of sheet cutouts (4). The C-shaped tape core parts (1) may be in two sections with an air gap or undivided. If the latter are undivided, the coil former must be in two sections. Alternatively, the coil former may be injection-moulded with C-shaped core parts in the mould.

Figure 7 comprises magnetic cores with two coils, but the same technology may be applied to magnetic circuits with three coils, for 3-phase current, as well as for four coils and a greater number of coils. According to the figure, the core comprises two units each with two C-shaped tape core

parts (1) and each encompassed by a coil. The outer circuit of the units is magnetically connected by means of two sheet cutout packages with retangular sheet cutouts (6).

Figure 8A shows a magnetic circuit with two coils comprising, on the one hand, a conventional tape core (2), whereby each of the inner parts of its two parallel core parts is assembled in a coil together with a first C-shaped tape core part (1) and two sheet cutout packages (3) magnetically connecting the first core parts (1) with one another.

Figure 8B shows a second core with three inner parts (three coils), two conventional tape cores (2) and two first C-shaped tape core parts (1). Four or two sheet cutout packages (4) magnetically connect the first tape core parts (1) with one another.

In figures 8A and 8B dot-dash lines indicate the contours of conventional types of tape core.

According to figure 9, a package of rectangular sheet cutouts (4) is placed between the tape core parts of the inner parts, as a result of which the area of the inner part is increased.

Figures 10-11 show core types made from sintered soft magnetic ferrite material. In figures 10, 11A and 11B dot-dash lines indicate the contours of conventional core types.

Claims

1. A soft magnetic core in a closed electromagnetic circuit comprises one or two inner parts encompassed by winding and at least one outer part which is not encompassed by winding c h a r a c t e r i s e d in that the core comprises a package of sheet cutouts consisting of soft magnetic material and constituting first sheet cutouts (1, 4 and 13, with at least one sheet cutout constituting at least one closed circuit loop, whereby one or two circuit parts referred to as the inner part are encompassed by at least one winding and in that at least one part of that part of the sheet cutouts which is not encompassed by the winding and constitutes the outer circuit referred to as the outer part has a smaller flux area than the inner part,
in that to that part of the outer part of the first sheet cutouts which has a smaller core area than the inner part are connected sheet cutouts constituting second sheet cutouts (2, 5 and 14) mounted on at least one side of the package with the first sheet cutouts parallel and tight against that part of the first sheet cutouts which has a reduced area and, as a result, that the combined area within that part of the core is increased to the required extent,
in that to that part of the outer part of the first sheet cutouts which has a smaller core area than the inner part is connected, alternatively instead of the second sheet cutouts, a wound tape core which is closed and of rectangular ring shape (3, 6) or C-shaped and mounted at least on one side of the package with the first sheet cutouts parallel and against that part of the first sheet cutouts which has a reduced area and, as a result, in that the combined area within that part of the core is increased to the required extent.

2. A soft magnetic core according to claim 1, c h a r a c t e r i s e d in that the first sheet cutouts (1) comprise one or two parallel inner parts which are joined together by outer parts so that the entire outer part has the shape of a closed rectangular frame,
in that the second sheet cutouts (2) have the shape of a closed rectangular frame consisting of closed sheet cutouts or of laminated design or consisting of complementing sheet cutout parts jointly forming a rectangular frame,
or in that, instead of the second sheet cutouts, a closed tape core of rectangular ring shape (3) is fitted.

3. A soft magnetic core according to claim 1, c h a r a c t e r i s e d in that the first sheet cutouts (1) comprise only one inner part encompassed by winding and joined together by only one C-shaped outer part and in that the second sheet cutouts (2) which are connected to the outer part of the first sheet are C-shaped,
or in that a C-shaped tape core part is fitted instead of the second sheet cutouts.

4. A soft magnetic core according to claims 1, 2 and 3, c h a r a c t e r - i s e d in that the core comprises, in addition to first sheet cutouts (1, 4 and 13) and second sheet cutouts (2, 5, 6 and 14), at least two sheet cutout units, referred to as third sheet cutouts (7-11, 15) placed at right angles against the first and second sheet cutouts and magnetically connecting the ends of the inner part of the first sheet cutouts with the outer part of the second sheet cutouts.

5. A soft magnetic core in a closed electromagnetic circuit comprises at least two inner parts encompassed by winding and at least two outer parts not encompassed by winding, c h a r a c t e r i s e d in that the core comprises a package of sheet cutouts consisting of soft magnetic material constituting first sheet cutouts (1, 4) with at least one sheet cutout constituting at least one closed circuit loop, whereby at least two circuit parts referred to as the inner part are each encompassed by at least one winding and in that at least one part of that part of the outer circuit of first sheet cutouts which is not encompassed by winding, the so called outer part, has a smaller flux area than the inner part,
in that to that part of the outer part of the first sheet cutouts the core area of which is smaller than the inner part is connected at least one package of sheet cutouts referred to as second sheet cutouts (2, 3 and 5), the shape of which is a rectangular closed ring, or a part thereof which is mounted at right angles in relation to the sheets of the first sheet cutouts,
in that the second sheet cutouts encompass with their inner edges that part of the first sheet cutouts the flux area of which is smaller than the inner part, as a result of which the combined area within the outer part is increased to the required extent,
or in that second sheet cutouts are designed in so called laminated manner from at least two complementary sheet parts.

6. A soft magnetic core in a closed electromagnetic circuit comprises at least one inner part encompassed by winding and consists of two parts of wound tape core of soft magnetic material with at least one turn, whereby the parts are placed with the sheet sides turned towards one another and at least one outer part not encompassed by winding, c h a r a c t e r i s e d in that each of the tape core parts of the inner part located within the coil is a part of a tape core body in the shape of a closed rectangular frame and consists of a straight part and two angularly bent parts at the ends of the straight part, or in that at least one of the tape core parts of the inner part is subdivided by a plane at right angles to the longitudinal direction of the tape core part within the longitudinal extent of the inner part, in that two tape core parts as described above are placed with the sheet sides turned towards one another and with the four angularly bent parts constituting a part of the outer part directed outward in opposite directions,
in that the two sheet core parts as above are referred to as the first sheet core unit (1),
and in that in addition at least one second core part (2, 4, 5 and 6) joins together the above outer parts of the first tape core unit by means of at least two magnetic joints with the side edges of the tape sheets pertaining to the first tape core unit.

7. A soft magnetic core according to claim 6, c h a r a c t e r i s e d in that the core comprises at least one first tape core unit (1) the inner part of which is encompassed by winding and the outer parts of which are magnetically connected, at least on one side of the side edges of the core sheets pertaining to the outer parts of the tape core unit of at least one second C-shaped tape core part (2, 5) with the cross-sectional area of the tape core sheets pertaining to the second tape core part, said cross-sectional area being at right angles to the longitudinal direction of the tape core, or of at least one second package of sheet cutouts (4) shaped as half of a rectangular ring.

8. A soft magnetic core according to claim 6, c h a r a c t e r i s e d in that the core comprises at least two first tape core units (1), the inner parts of which are encompassed by winding while the side edges of the inner part's tape sheets are turned towards one another and in that the outer parts of the first tape core units are connected by magnetic joints with the side edges of the tape sheets pertaining to

the first tape core units or at least two other core parts (6) in the form of sheet cutout packages, each with at least one sheet cutout.

9. A soft magnetic core in a closed electromagnetic circuit comprises at least two inner parts each consisting of two parts of wound tape core with at least one turn, whereby the parts are placed with the sheet sides turned towards one another and are encompassed by winding and at least two outer parts which are not encompassed by winding,
c h a r a c t e r i s e d in that one of the two tape core parts located within a coil of the inner part is a part of a tape core body having the shape of a closed rectangular frame and consists of a straight part and two parts angularly bent at the ends of the straight part and referred to as the first tape core part (1),
or in that the first tape core part (1) is subdivided within the longitudinal extent of the inner part by a dividing plane at right angles to the longitudinal direction of the tape sheets pertaining to the tape core part,
in that the first tape core part (1) is placed in a first coil together with a first inner part of a first conventional tape core (2), with the sheet sides turned towards one another, whereby the angularly bent parts extend forwards beyond the ends of the coil and are turned away from the conventional tape core and constitute a part of the outer part,
in that a second tape core part such as the first tape core part referred to as the second first tape core part (1) is located in a second coil together with the second inner part of the first conventional tape core (2), with the sheet sides turned towards one another, whereby the angularly bent parts of the first tape core part which extend forward beyond the ends of the coil are turned away from the second inner part of the first conventional tape core (2) and have a direction opposite to the outer parts of the first tape core part and constitute a part of the outer part,
in that the bent parts of the first tape core part (1) and the second first tape core part (1) which extend forward beyond the ends of the coil and are turned away from one another are connected by at least four magnetic joints of at least two sheet cutout packages (3) with not less than one sheet, at least on one side of the bent tape core parts at either side of the coil ends, with the side edges of the tape sheets pertaining to the first and second tape core parts,
or in that the soft magnetic core in an electromagnetic circuit

comprises two conventional tape cores (2), one first tape core part (1) and a second first tape core part (1) and three inner parts, whereby the first inner part comprises the inner part of the first tape core part (1) together with the first inner part of the first conventional tape core (2), the second inner part comprises the second inner part of the first conventional tape core (2) and the first inner part of the second conventional tape core (2) and the third inner part comprise the second inner part of the second conventional tape core (2) together with the inner part of the second first tape core part (1), all the inner parts being mounted with the sheet sides turned towards one another,

in that the bent parts of the first tape core part (1) and the second first tape core part (1) which extend forward beyond the ends of the coil are turned from one another and are connected with one another by at least four magnetic joints of at least two sheet cutout packages (4) with not less than one sheet, at least on one side of the sheet core parts as described above on either side of the coil ends, with the side edges of the tape sheets pertaining to the first and second tape core parts.

10. A soft magnetic core according to claims 6-9, c h a r a c t e r i s e d in that the core comprises, in addition, at least one package of rectangular sheet cutouts (4) with at least one sheet cutout consisting of soft magnetic material which has the same total width and height as the tape core parts and in that the rectangular sheet cutouts (4) are located between tape core parts parallel with the sheet sides of the tape core parts.

11. A soft magnetic core consisting of sintered, soft magnetic ferrite material in a closed electromagnetic circuit comprises one inner part encompassed by winding and an outer part which is not encompassed by winding, whereby the inner part comprises a stack with rectangular or circular cross-section and an outer part of rectangular cross-section. extends beyond the ends of the coil, connects the ends of the inner part and has the shape of half a rectangular frame, c h a r a c t e r - i s e d in that the outer part extends beyond the stack in the direction at right angles to the extent of the outer part and the centre line of the inner part and is wider than the cross-section of the inner part (stack) at least on one side of the stack and the outer extent is delimited by at least one outer side plane.

in that the space between the outer side plane or the side plane of the outer part which extends beyond the stack and the inner part of the stack is comprised by the winding and in that the outer side plane is parallel.

12. A soft magnetic core of sintered soft magnetic ferrite material in a closed electromagnetic circuit comprises at least two inner parts encompassed by winding (coil) and at least two outer parts which are not encompassed by winding, whereby the inner parts consist of parallel stacks of rectangular or circular cross-section and the outer parts have a rectangular cross-section extending beyond the ends of the coil and connecting the ends of the inner parts which are turned in the same direction, c h a r a c t e r i s e d in that the outer parts are formed as a flat rod part which is at right angles to the stack of the inner parts and to the plane connecting the centre lines of the stacks, in that the outer parts or the inner parts are wider in the direction at right angles to the plane connecting the centre lines of the stacks and the cross-section of the inner parts (stacks) on one side of the stacks in the direction at right angles to the plane connecting the centre lines of the stacks at least on one side of the ends of the stacks,
in that the outer parts which are wider than the inner parts are delimited by an outer side plane parallel to the plane connecting the centre lines of the stacks and in that the space between the outer side plane and the outer part which is wider than the stacks and the stacks of the inner parts comprise a winding.

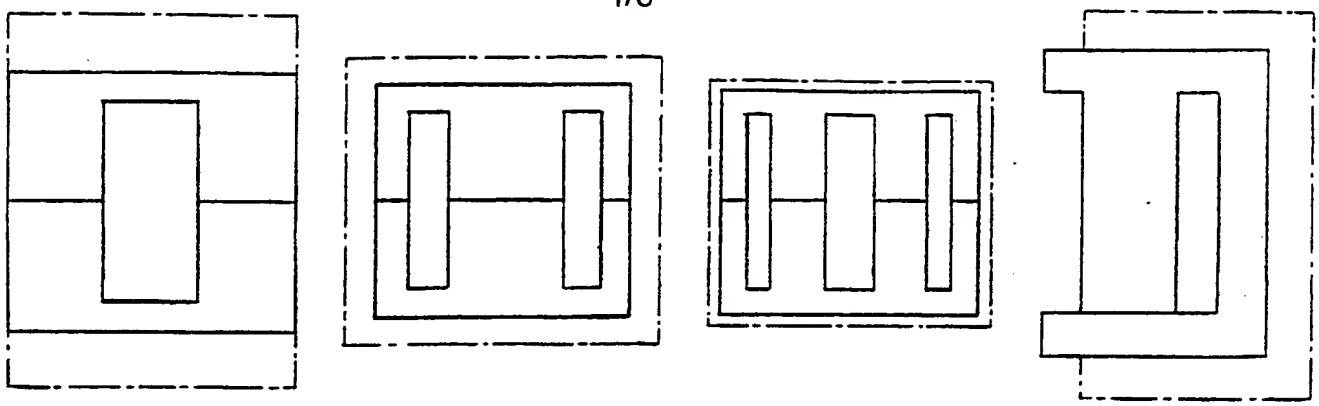

FIG. 1

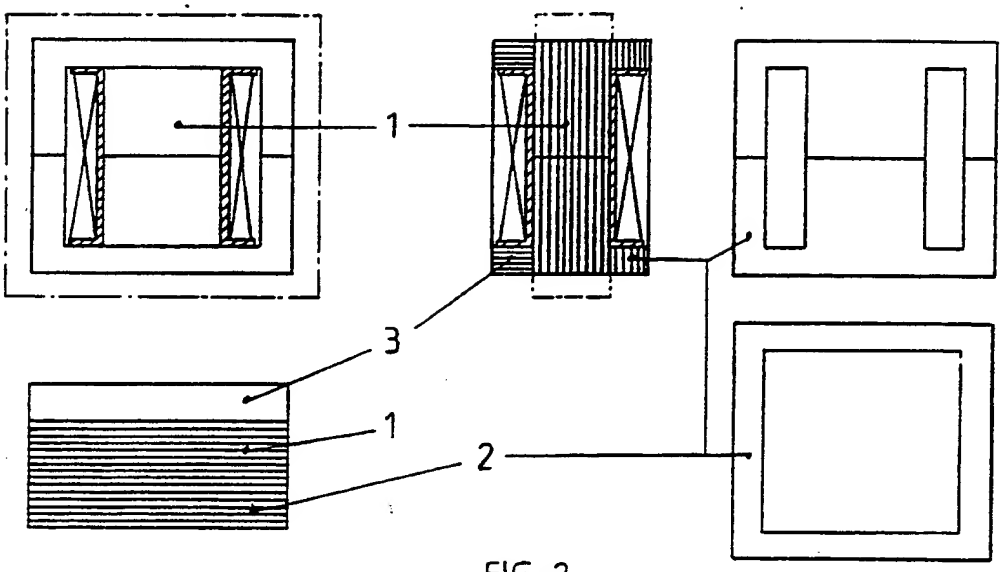


FIG. 2

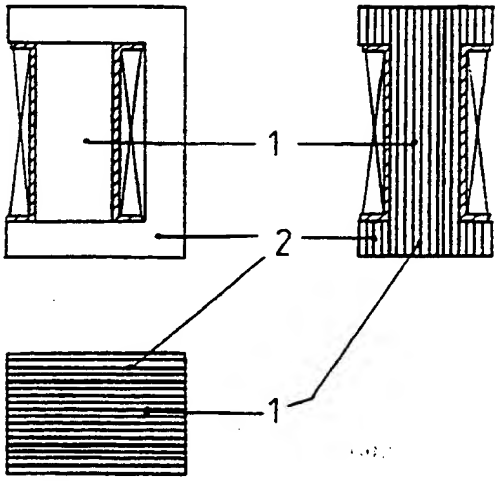


FIG. 3

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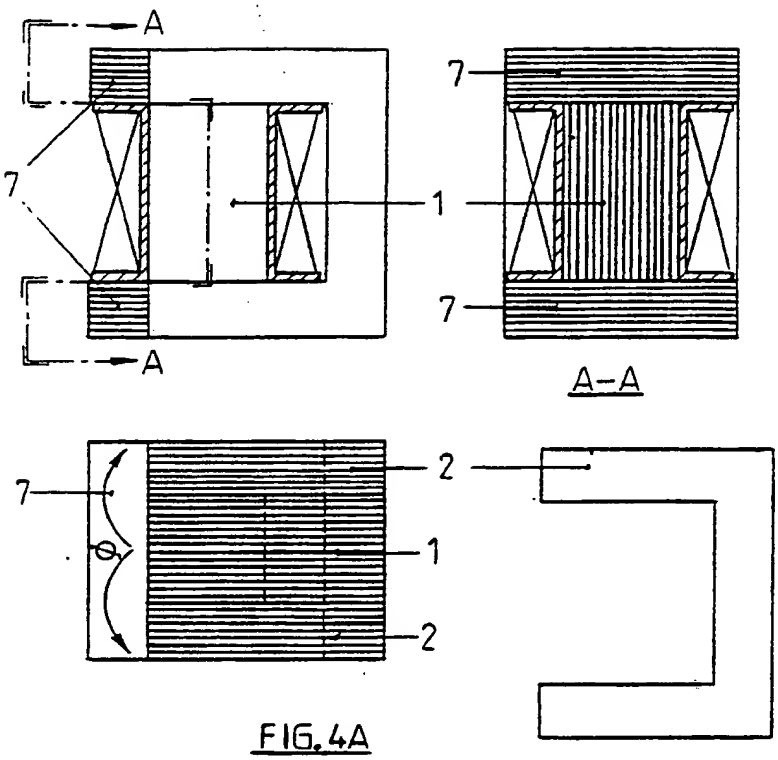


FIG. 4A

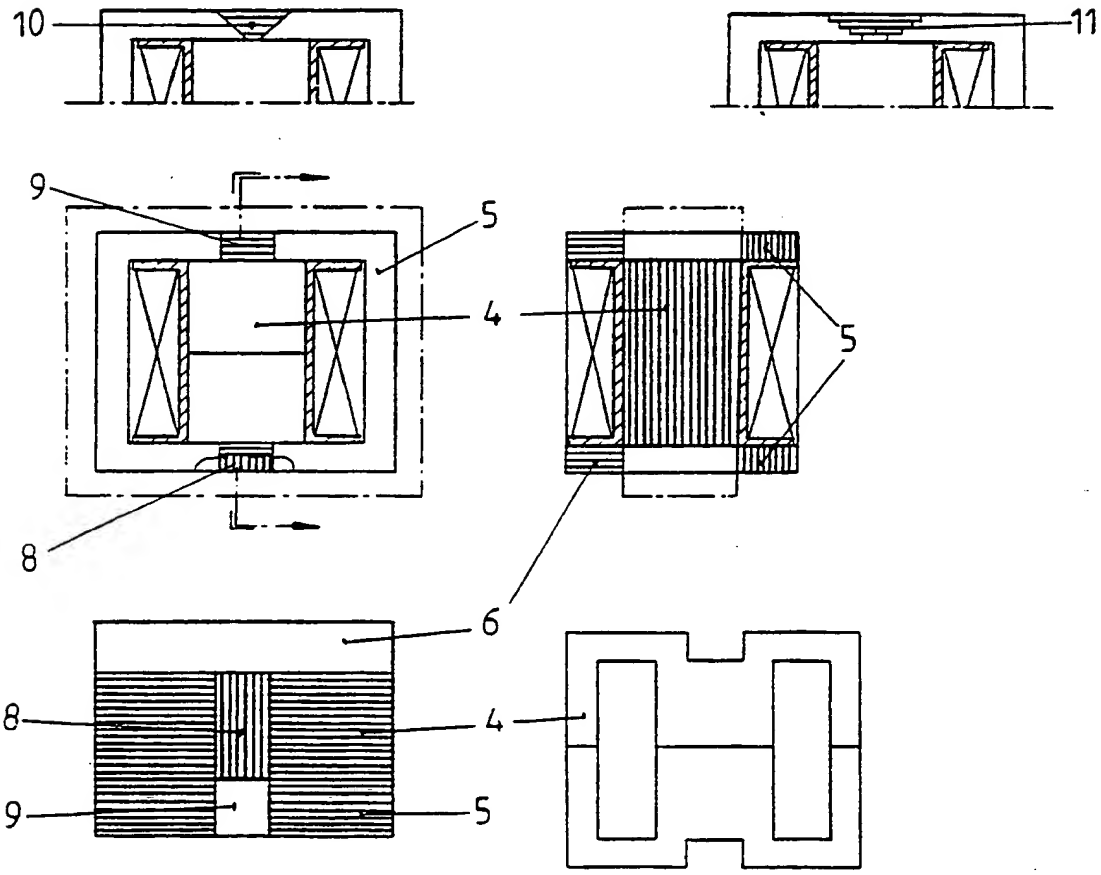


FIG. 4B

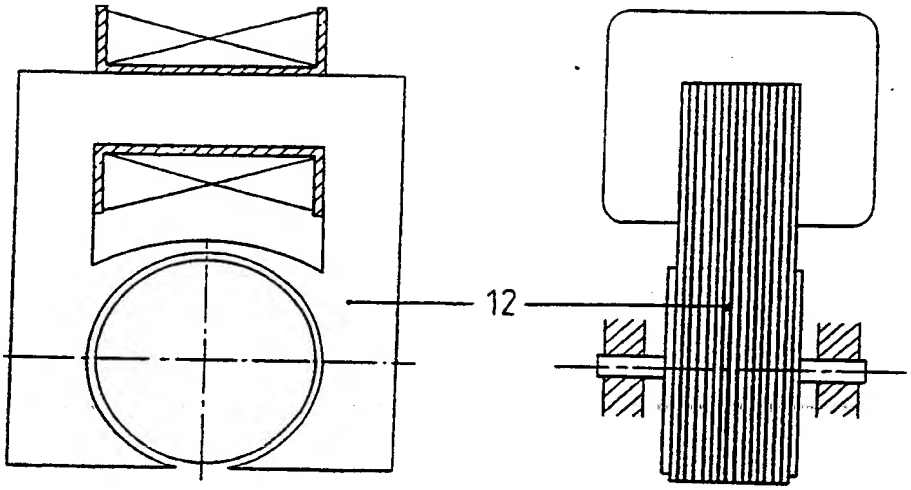


FIG. 4C

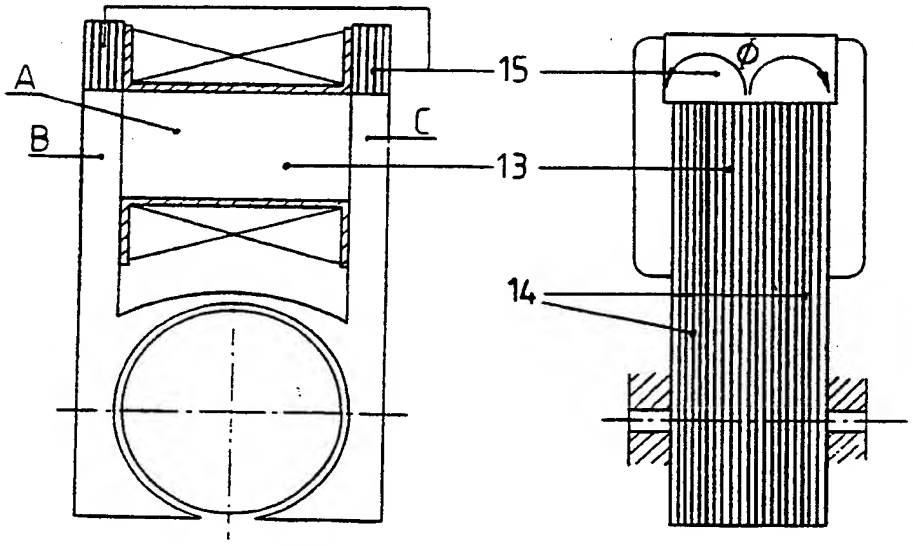


FIG. 4D

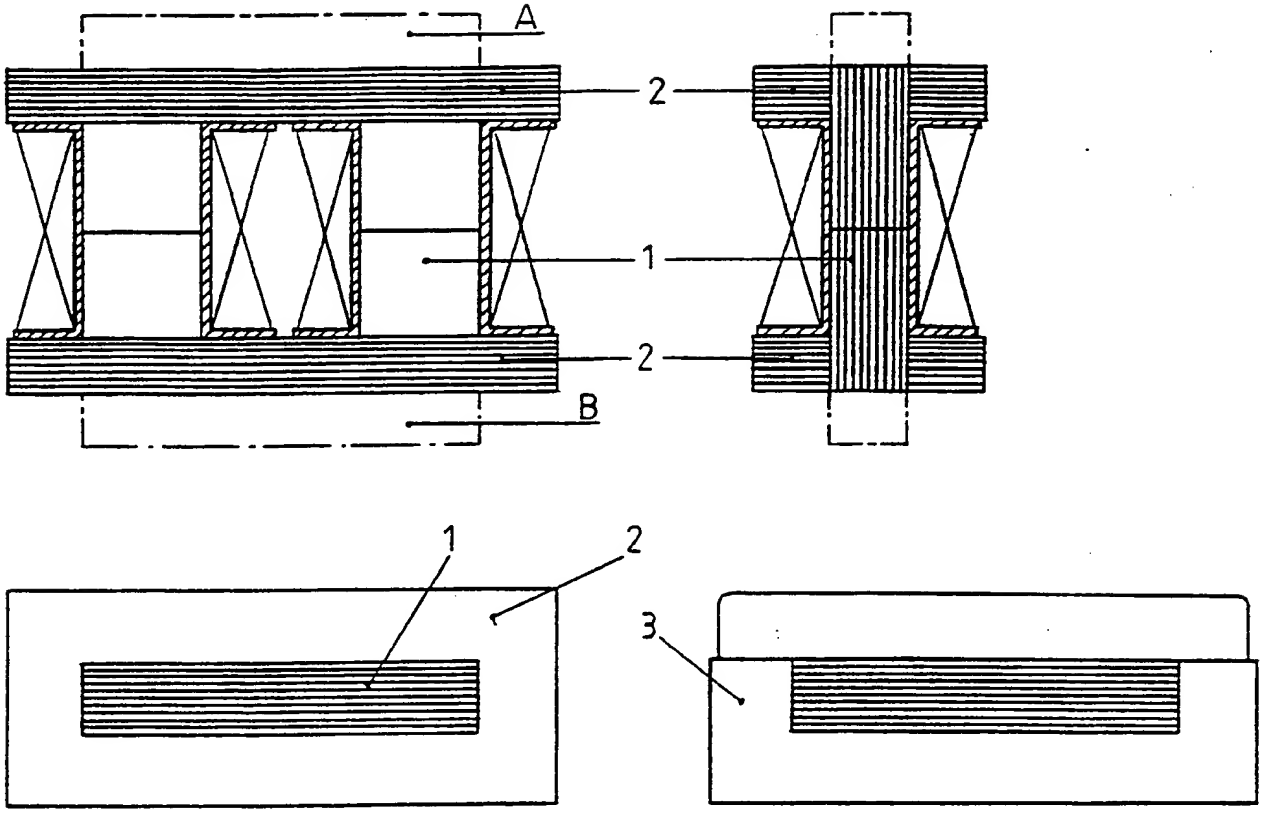


FIG. 5A

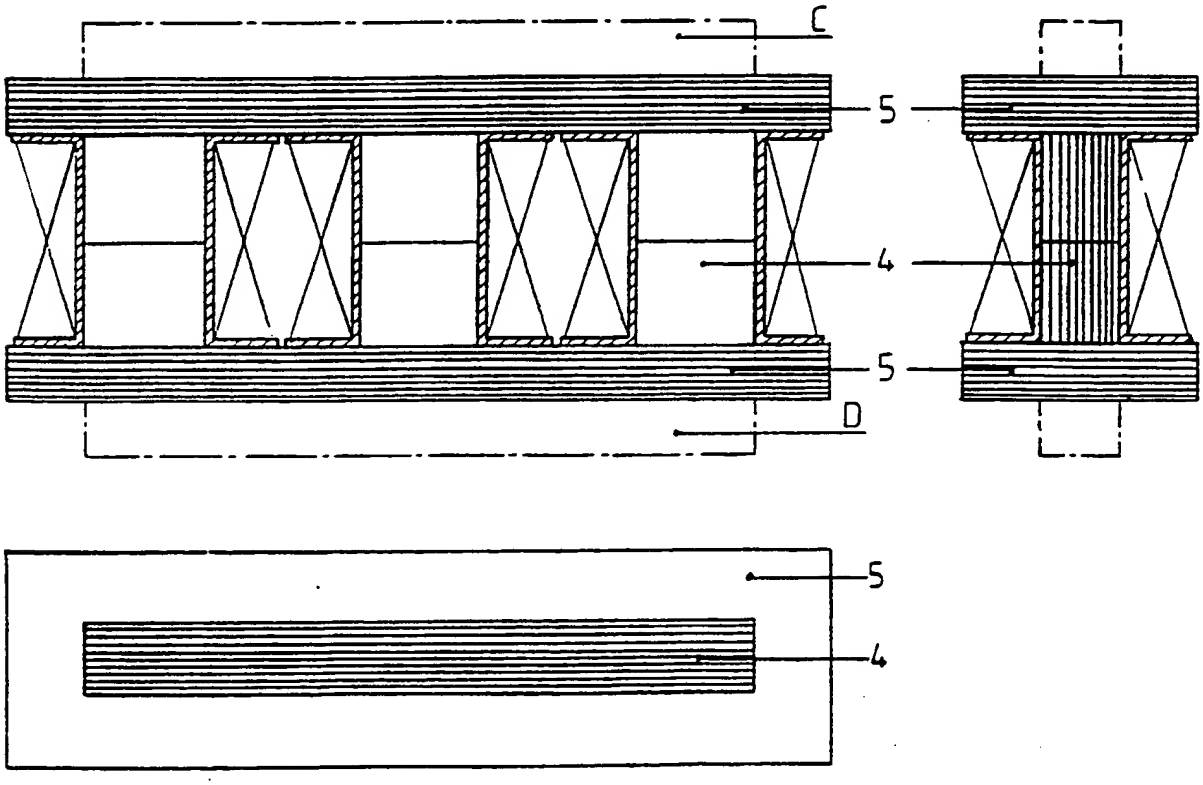


FIG. 5B

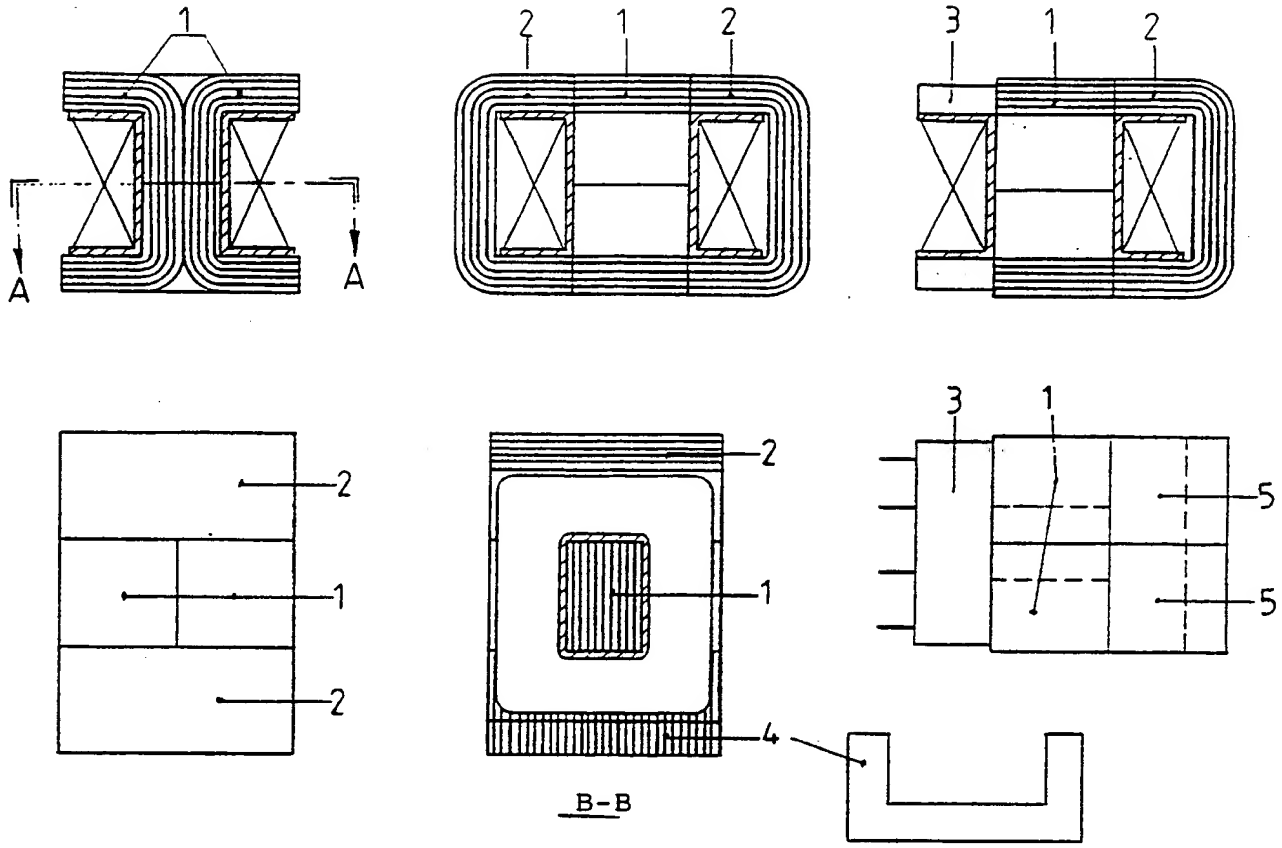


FIG. 6

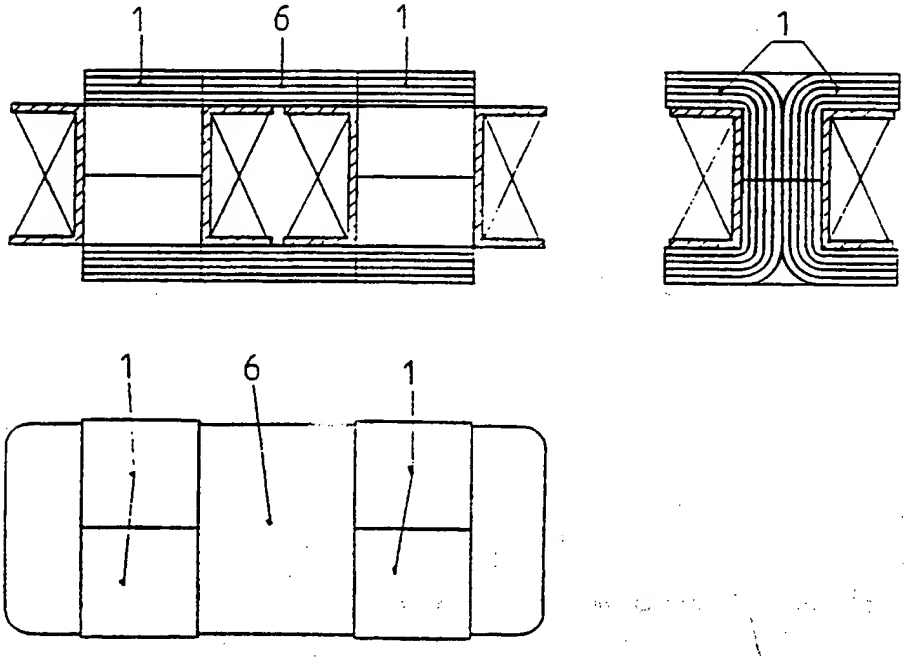


FIG. 7

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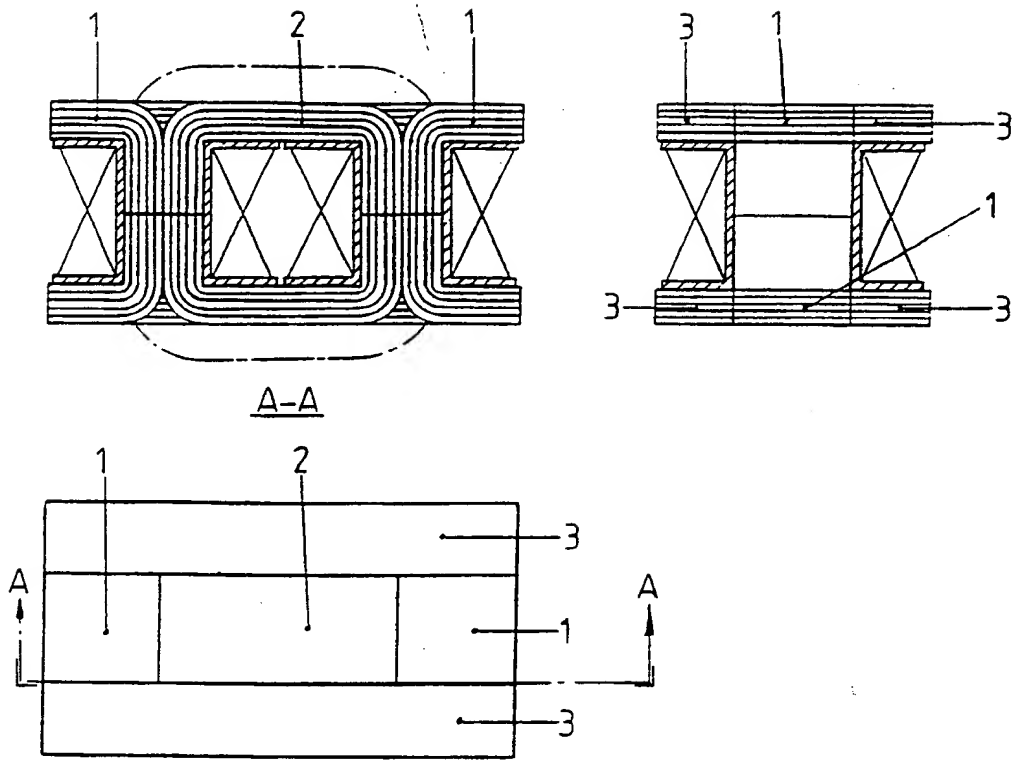



FIG.8A

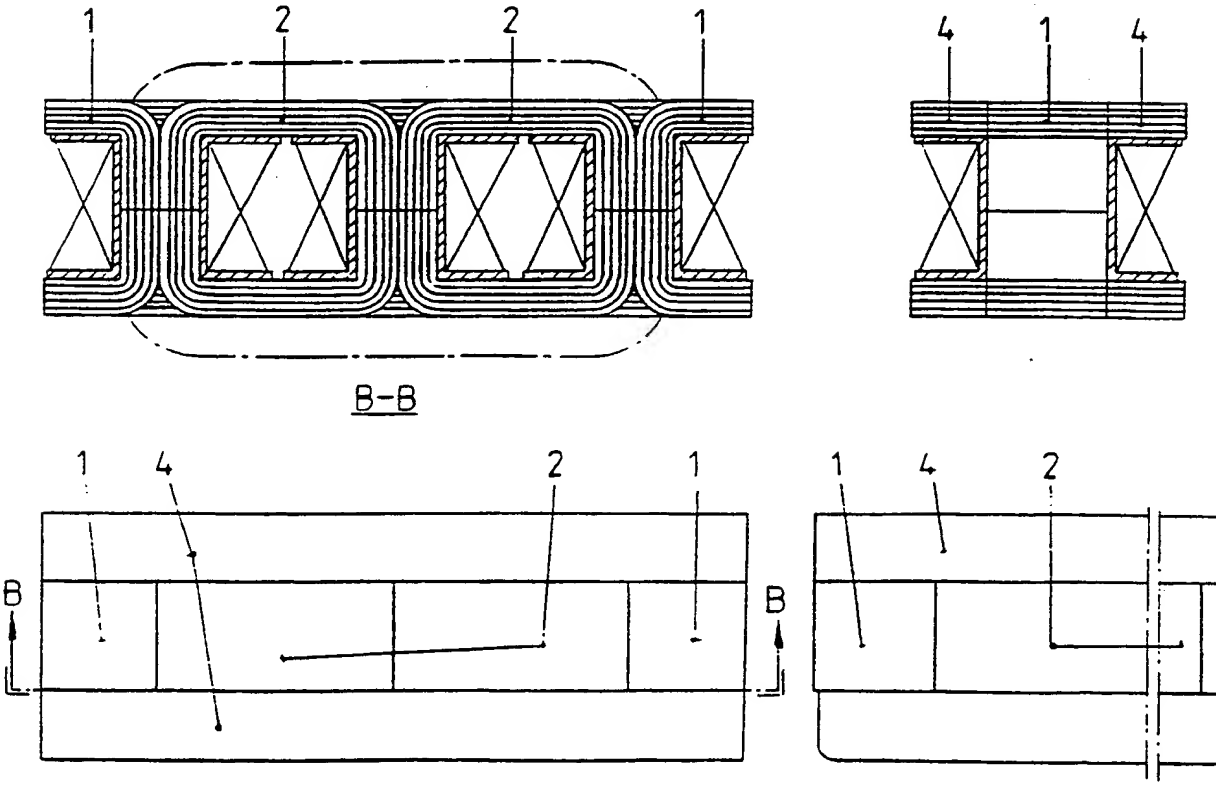



FIG. 8B

SUBSTITUTE

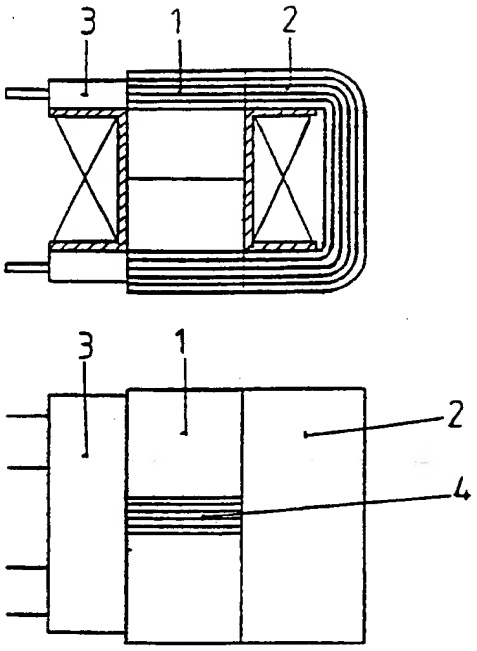
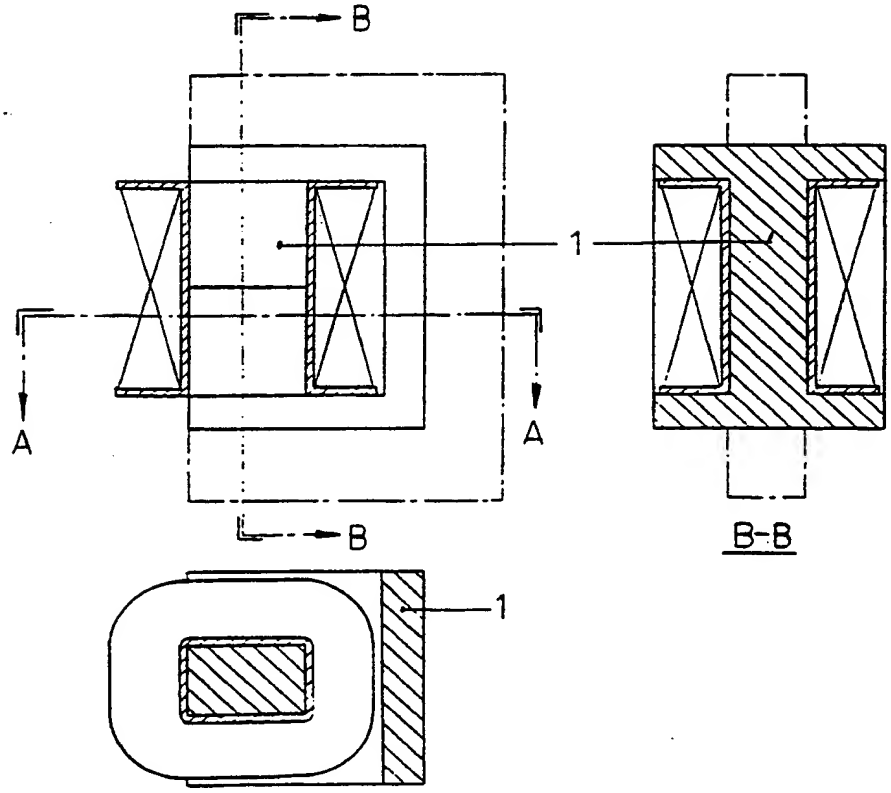



FIG. 9




A-A FIG. 10

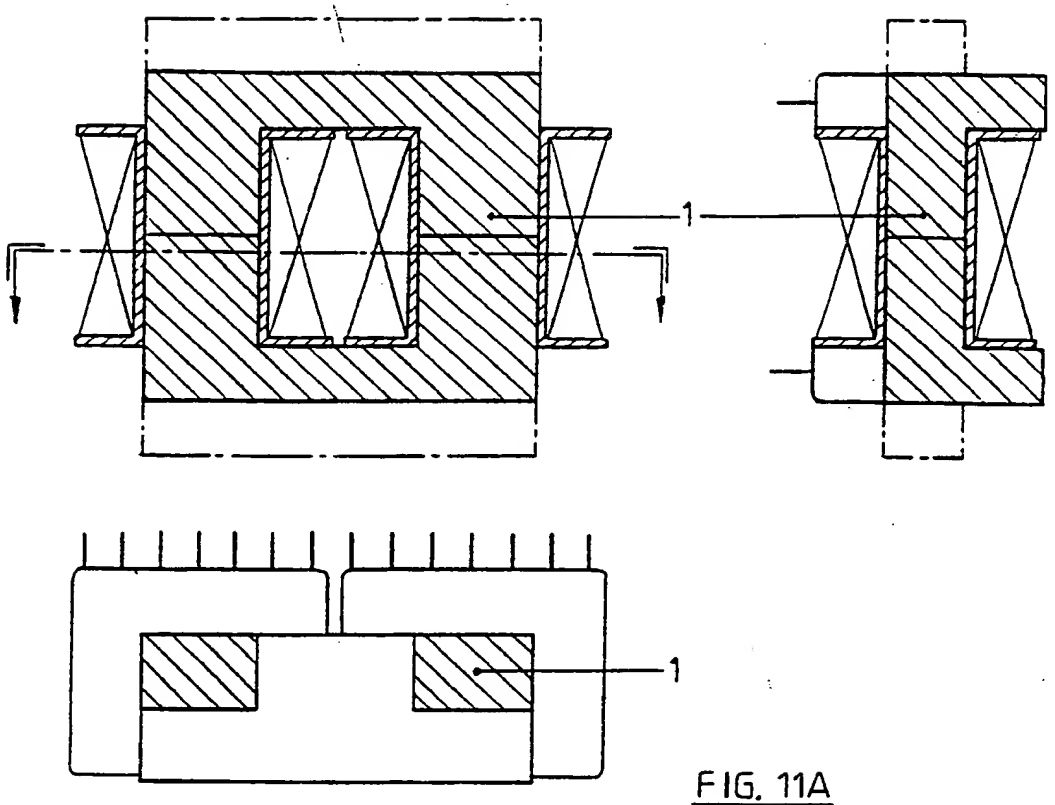



FIG. 11A

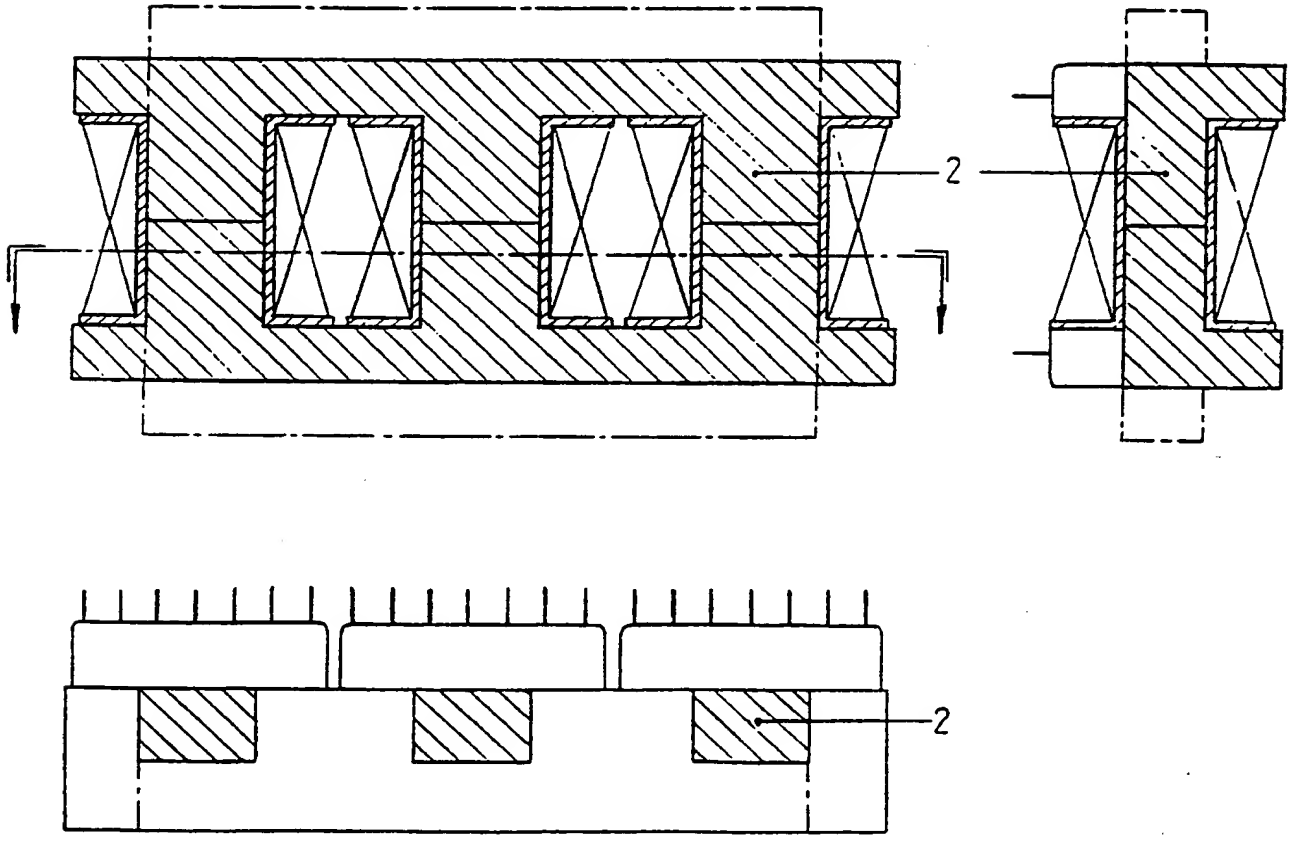



FIG. 11B

# INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 91/00252

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: H 01 F 27/24

## II. FIELDS SEARCHED

Minimum Documentation Searched[7]

| Classification System | Classification Symbols |
|---|---|
| IPC5 | H 01 F |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

## III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

| Category * | Citation of Document,[11] with indication, where appropriate, of the relevant passages[12] | Relevant to Claim No.[13] |
|---|---|---|
| A | SE, C, 89233 (COMPAGNIE ELECTRO-MECANIQUE) 11 May 1937, see the whole document -- | 1,5 |
| A | GB, A, 660965 (THE BRITISH THOMSON-HOUSTON COMPANY) 14 November 1951, see the whole document -- | 1,5,6,9 |
| A | GB, A, 830688 (GENERAL ELECTRIC COMPANY) 16 March 1960, see the whole document -- | 1 |
| A | DE, C, 148023 (ELEKTRIZITÄTS-ACTIEN-GESELLSCHAFT) 4 February 1904, see the whole document -- | 1 |

* Special categories of cited documents:[10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

## IV. CERTIFICATION

| Date of the Actual Completion of the International Search | Date of Mailing of this International Search Report |
|---|---|
| 13th June 1991 | 1991 -07- 01 |
| **International Searching Authority** | **Signature of Authorized Officer** |
| SWEDISH PATENT OFFICE | Magnus Lisk<br>Magnus Westöö |

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

| Category * | Citation of Document, with indication, where appropriate, of the relevant passages | Relevant to Claim No |
|---|---|---|
| A | EP, A1, 0245083 (TDK CORPORATION)<br>11 November 1987,<br>see the whole document<br>--<br>-------- | 11,12 |

# ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. PCT/SE 91/00252

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 91-05-29
The Swedish Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| SE-C- 89233 | 37-05-11 | NONE | |
| GB-A- 660965 | 51-11-14 | NONE | |
| GB-A- 830688 | 60-03-16 | NONE | |
| DE-C- 148023 | 04-02-04 | NONE | |
| EP-A1- 0245083 | 87-11-11 | JP-A- 62226096<br>US-A- 4760366 | 87-10-05<br>88-07-26 |